

## DOWNSIZING ANTENNA TECHNOLOGIES FOR MOBILE AND SATELLITE COMMUNICATIONS\*

J. Huang, A. Densmore, A. Tulintseff, and V. Jannejad

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California 91109

**Background:** Due to the increasing and stringent functional requirements (larger capacity, longer distance, etc..) of the modern day communication systems, higher antenna gains are generally needed. This higher gain implies larger antenna size and mass which are undesirable to many systems. Consequently, downsizing antenna technology becomes one of the most critical areas for research and development efforts. Techniques to reduce antenna size can be categorized and are briefly discussed as follows:

### 1. Downsizing by antenna techniques:

- o Use printed array - By using printed array, such as the microstrip patches, antenna thickness can be significantly reduced which, in many cases, allows conformal mounting of the antenna.
- o Develop efficient array feed - Among two similar array antennas with identical gains, the one with the more efficient feed system (lower insertion loss) can achieve a relatively smaller aperture size.
- o Use shared aperture technique - When a system requires separate transmit and receive frequencies or requires multiple functions with different frequencies, a single antenna aperture shared by all these frequencies can significantly reduce system size and mass.
- o Reduce peripheral component size - By reducing sizes of an antenna's peripheral components, such as the use of MMICs for phase shifters and distributed amplifiers in an active phased array, the overall antenna system can achieve smaller size.
- o Develop superdirective array - Superdirective array technique allows a smaller antenna aperture to achieve a relatively larger gain. However, the validity of this technique has been controversial. More research effort is needed in this area.

### 2. Downsizing by raising the operating frequency: If the system operating frequency is doubled, the antenna dimension can be reduced by half (aperture area reduced to 1/4) while maintaining the same antenna gain. Space loss associated with the higher frequency can be compensated by keeping the size of the antenna on the other end of the communication link the same as prior to the frequency increase.

The JPL antenna technologies that have either recently been developed or proposed for the future communication systems have mostly involved downsizing technologies discussed above. These technologies have been applied in two areas, mobile antennas and satellite antennas, which are separately discussed below.

**Mobile Antennas:** The mechanically steered microstrip Yagi array [1] that developed for the NASA/JPL's Mobile Satellite (MSAT) program utilized the printed array technology and the efficient array feed technique. This antenna, as shown in Figure 1, has achieved the lowest antenna height (3 cm) and diameter (53 cm) known to date for all the L-band mechanically steered antennas. Across the elevation region of 20° to 60° above the horizon, the antenna achieved maximum gain of 14 dBi and minimum gain of 9.5 dBi. The electronically steered phased array [2] that developed for the same MSAT program also utilized the printed array technology. Its peripheral components, such as phase shifters, power dividers, driver circuits, are all etched on the same stripline layer below the radiators. The antenna, as shown in Figure 2, has achieved the lowest height (1.8 cm) among all the L-band electronically steered antennas developed to date.

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to have smaller antenna size, two types of antennas are being developed for JPL's ACTS Mobile Terminal [3] by raising frequency to Ka-band. One is the mechanically steered elliptical reflector antenna which, shown in Figure 3, has a base diameter of 22 cm and a height of 10.5 cm. The other is the mechanically steered active array as shown in Figure 4. Both antennas will provide a gain in the order of 22 dBi. The active array uses printed dipoles at 30 GHz for transmit and printed slots at 20 GHz for receive. Both the dipoles and slots share the same aperture. (16 cm x 13 cm). MMIC III's and LNAs are to be used as active components for this array. In addition to the above two antennas, several Ka-band antenna concepts have also been proposed for the future Personal Access Satellite System (PASS) [4,5]. One example is the head-mounted array that can be either mechanically or electronically steered to track the satellite. This head-mounted antenna, as shown in Figure 5, not only permits user's both hands to be free for performing other functions but also can avoid possible radiation hazard to the head.

**Satellite Antennas:** A deep space mission to Saturn, named Cassini, requires its antenna system to perform multiple functions (radio science, radar mapping, telecommunication, etc.) at four different frequency bands - S, X, Ku, and Ka. To alleviate the satellite's size and mass burdens, a single shared-aperture Cassegrain reflector antenna system, as sketched in Figure 6, is being developed to have all four-frequency capabilities. Several technical challenges, such as the frequency selective subreflector (FSS) [6] and the multiple-beam Ku-band array feeds, [7] have been encountered. Both experimental and theoretical study results have demonstrated that such a multi-function and multi-frequency antenna system is highly feasible.

Microspacecraft technology is being planned for development to study Asteroids, Comet, and other planets. Each microspacecraft, having size in the order of 0.5 meter, is required to have high gain antenna with small size and mass. Printed microstrip array, planar slotted waveguide array, and surface-mount flat reflector at Ka-band frequency are being proposed to counter the size and mass problems. The flat reflector, illustrated in Figure 7, combines the technologies of microstrip patch and reflectarray [8] to allow surface mounting the reflector antenna onto the microspacecraft.

For NASA's next generation scatterometer application, an orthogonally scanned dual-beam phased array antenna at Ku-band is being proposed [9]. This antenna, shown in Figure 8 and having size 1 m x 1 m, employs printed array technology and shared aperture solution to significantly reduce size and mass. Efficient series feed technique is also used to feed a large number of patches (approximately 80 patches in each row). Due to the orthogonal feeding, all the patches need to be identical. It is quite a challenge to series feed a large number of identical patches while maintaining uniform amplitude across the aperture.

## Reference:

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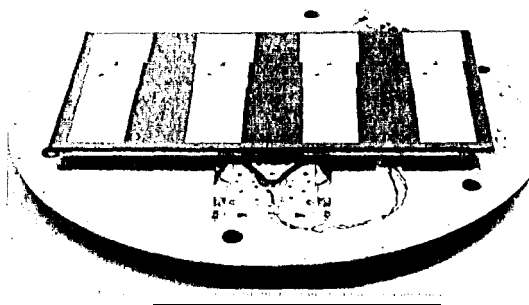


Figure 1. Planar microstrip Yagi array for mobile satellite communication.

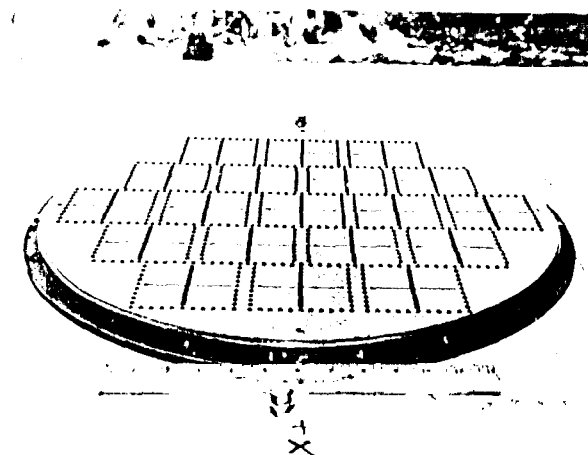


Figure 2. Low-profile phased array for mobile satellite communication.



Figure 3. Small elliptical reflector for ACTS mobile terminal.

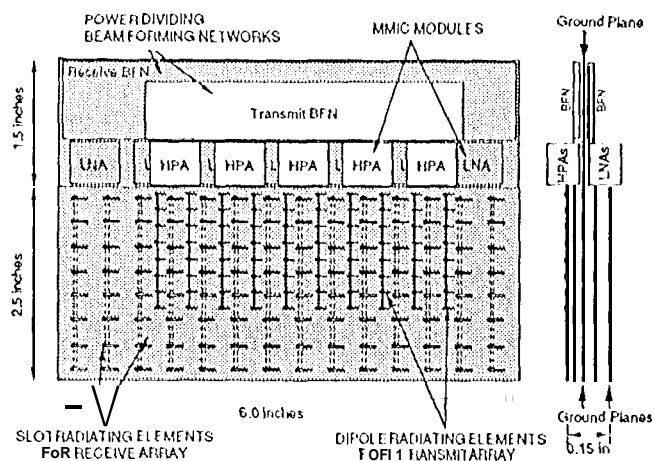


Figure 4. Printed share-aperture active array for ACTS mobile terminal.



Figure 5. Ka-band head-mounted array for personal satellite communication.

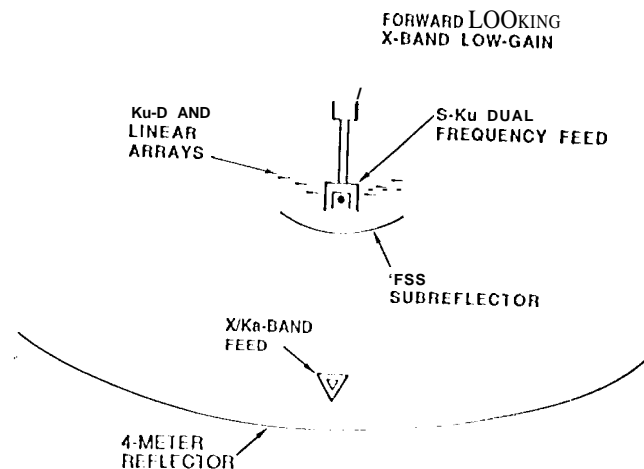


Figure 6. Multi-function and multi-frequency Cassini reflector antenna.

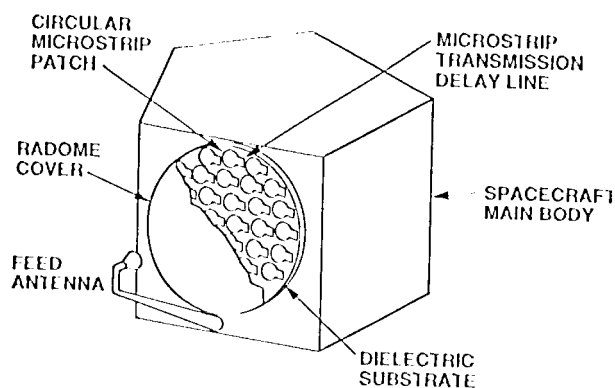


Figure 7. Microstrip reflectarray for microspacecraft application.

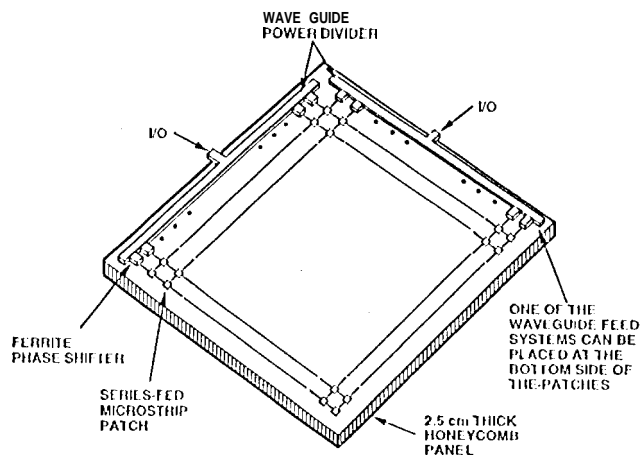


Figure 8. Orthogonally scanned shared-aperture microstrip array for Ku-band scatterometer application.